TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 811

THE EFFECT OF METHODS OF TESTING ON THE ULTIMATE LOADS SUPPORTED BY STIFFENED FLAT SHEET PANELS UNDER EDGE COMPRESSION

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SUMMARY

Two series of stiffened flat sheet specimens were tested under edge compression using various end conditions: round ends (knife-edge bearings), flat ends, and continuous panels. The specimens consisted of aluminum-alloy flat sheet stiffened by three hat-shaped extruded aluminum-alloy stiffeners. One series of specimens used B. & S. No. 10-gage (0.102 in. nominal) sheet and the other used B. & S. No. 16-gage (0.051 in. nominal) sheet.

The results of the tests indicate that in the restricted range of slenderness ratios considered, the length of specimen has an insignificant effect on the ultimate compressive load. The condition of the ends, whether round or flat, has only a small effect on the strength of the specimen if the buckling strengths of the sheet panels and stiffeners are nearly equal. In the case of specimens where either the sheet or the stiffener is relatively stronger than the other, the use of flat ends will result in a higher test load than will the use of round ends. The ultimate loads supported by specimens continuous over several hinged supports are close to those supported by simple specimens tested with flat ends. Testing continuous specimens offers a means of obtaining high ultimate loads without introducing the questionable high degree of end restraint involved in the ordinary flat-end test.

INTRODUCTION

Stiffened sheet is widely used as a strength member in aircraft and other lightweight construction. The principal loads lie in a plane parallel to the sheet and act in the direction of the stiffeners. In connection with the design of stiffened sheet for use in aircraft, manufacturers frequently base the strength of a unit of the structure on test results from small specimens representing that particular design rather than rely entirely on computations or on the test of a complete unit. Usually the procedure consists in preparing a panel using the sheet thickness and the stiffener spacing proposed for the new design. The length of the panel is made equal to the spacing of the transverse bulkheads or stiffeners, and the width is some dimension that can be accommodated by the testing equipment. After the specimen has been machined so that the ends are flat and parallel, it is loaded to failure in edge compression in a testing machine.

In making tests on small panels, the method of testing is often partly dependent on the design assumption, such as the assumption of zero restraint at the transverse supports. In this case, the specimens would probably be loaded through bearing blocks with knife edges or some other device that produces a small resistance to the rotation of the ends of the specimen. The assumption of a large amount of restraint or complete fixity at the ends of the panel length would be a basis for using some other type of loading device.

Tests were outlined to show the effects of different methods of testing on the ultimate strength of the specimen, with the belief that this information should be of considerable value to those responsible for establishing methods of routine testing in the aircraft industry. Tests were included to show the effects of extreme care in the preparation and alinement of the specimens.

DESCRIPTION OF SPECIMENS

The specimens used in this investigation are shown in figure 1 and are described in table I. The specimens with 10-gage sheet were designed to develop a stress at failure in both the sheet and the stiffener approximately equal to the yield strength of the material. The maximum unsupported width of any flat section in these specimens is about 18 times the thickness of the sheet and the spacing of the rivets is about 16 times the thickness of the flange of the stiffener, or about 12 times the sheet thickness. The basic length of specimen, 12 inches, gives a slenderness ratio of about 21, which, according to studies of column test data, should develop a stress equal to at least the yield strength of the material in a test with round ends.

The specimens with 16-gage sheet were designed so that the flat sheet would buckle at a stress somewhat below the yield strength of the material. Since the stiffener section is the same as that used in the set of specimens with 10-gage sheet, the stiffener is relatively stronger than the sheet in compression. When such a specimen is tested to failure under edge compression, the effective centroid of the section shifts as the buckling of the sheet progresses. Because of this shift in the position of the effective centroid, the method of test, whether with round or flat ends, is of much more importance than in the case of a more compact or a symmetrical section where the effective centroid does not shift as the load increases.

The mechanical properties of the materials used are given in table II and are in accord with the specifications for these materials.

The ends of all specimens, except specimen E in each series, were machined flat and parallel within the limits noted in table I before they were tested. The flatness of the ends was checked by thickness gages and a surface plate, and the parallelism of the ends was checked by measuring the length of the various elements of the cross section with an outside caliper, which used a dial gage as a measuring device. The dial gage was graduated to thousandths of an inch movement of the plunger so that differences of 0.0002 inch in the lengths of the various elements could be estimated.

In the case of specimen E of each series, the ends were merely sawed square by means of a movable-blade band saw. The cuts were made using only a slight pressure on the saw blade (2 lb), but no special jigs were used to hold the specimen. The measurements with the outside caliper indicated that the variation in the length of the elements of the sheet was 0.0115 inch in the case of the 10-gage sheet but only 0.0050 inch in the case of the 16-gage sheet. A much larger variation was found between the elements of the sheet and those at the tops of the stiffeners. As shown in table I, this variation amounted to about 0.039 inch. The out-of-flatness of the ends as revealed by comparison with a surface plate was about 0.014 inch in both cases.

TESTING EQUIPMENT AND METHODS OF TEST

The compressive tests on all the stiffened flat sheet panels except specimen H were made in a multiple-capacity Amsler hydraulic-type testing machine, the maximum capacity of which is 300,000 pounds. In the tests of the specimens with 10-gage sheet, the 200,000-pound load range was used, and in the tests of the specimens with 16-gage sheet the 100,000-pound load range was used. The testing machine is periodically inspected and in the recent calibration it was found to measure loads correctly within ±1 percent. The lower head of the testing machine is provided with a pair of tapered leveling rings by means of which the platen can be tipped about any axis in the plane of the surface. With this device the upper and the lower platens can be alined parallel within less than 0.0005 inch per foot. This adjustment of the platens counteracts the small errors in the lead screws of the testing machine.

The test on specimen H (only in the 16-gage sheet series) was made in a four-screw Olsen universal testing machine of 100,000-pound capacity. The platens of the testing machine were hardened steel plates without spherical seats or other devices to correct for nonparallelism. A calibration made just before the test showed the machine to measure loads correctly within ±1 percent.

A number of different loading conditions was used in these tests. For the various specimens of the two series they were as follows:

<u>Specimen A</u>. Platens supported on knife edges were used at each end of specimen A as indicated in figure 2. By means of the special leveling rings mentioned, the platens were alined parallel, in the direction of the knife edges, within 0.0005 inch in 12.5 inches. Since they were free to tip in the other direction, there was no adjustment to be made. The specimen was $9\frac{1}{2}$ inches long and the platens were $1\frac{1}{4}$ inches thick so the centers of rotation were 12 inches apart. The specimen was

carefully centered by measurement so that the centroidal axis of the ends of the specimen coincided with the plane of the knife edges. In order to remove any initial transverse curvature, the specimen was clamped between a pair of 1/2-inch square steel bars at each end.

Specimen B. The equipment for specimen B was the same as that used in the test of specimen A. The specimen was centered under load, that is, it was shifted laterally with respect to the plane of the knife edges at zero load following successive loadings until strain measurements on the sheet and the stiffeners indicated that the stress was nearly uniformly distributed. In the case of the specimen with 16-gage sheet the position finally used in the loading to destruction indicated a shift of about 0.03 inch at the top and a shift in the opposite direction of about 0.05 inch at the bottom, with respect to the position used in the test of specimen A. The final position of the specimen with 10-gage sheet indicated that the shift was practically zero.

Specimen C. Specimen C was tested as a column with flat ends, that is, the platens were fixed against tipping and turning. (See fig. 3.) A pair of small angle bars was clamped to the specimen to remove any initial lateral curvature. The specimen was then carefully centered on the lower platen. The length of the specimen was 12 inches. The results of a large number of column tests made in this machine in this manner indicated that the flat-end condition is practically equivalent to fixed ends. The effective slenderness ratio of this specimen is thus one half that of specimens A and B tested with round ends. Before the test, the platens were alined parallel within 0.0003 inch in 12.5 inches.

Specimen D. The method of test for specimen D was the same as that used for specimen C. The length of the specimen was 24 inches; so the effective slenderness ratio was equal to that of specimens A and B. The platens were alined parallel within 0.0005 inch in 12.5 inches.

Specimen E. The equipment and the setting of the platens for specimen E were the same as used with specimen C. The specimen was the same as specimen C except, as already mentioned, the ends were sawed but not machined. In centering the specimen in the testing machine it was found necessary to hold the specimen vertical on the lower platen. This added operation was necessary because the ends of the specimen were not normal to the axis of the specimen.

Specimen F. Specimen F was supported laterally at intermediate points so that it was continuous over three panels. The test set-up and the supporting frame are shown in figures 4 and 5. The platens were fixed against tipping and turning and were alined parallel within 0.0005 inch in 12.5 inches. One-inch square bars were securely attached to the specimen by means of screws through the flanges of the stiffeners and the sheet and were threaded into the bars. The bars in turn were connected to a frame consisting of 4-inch steel I-beams supported by the upper casting of the testing machine. The connecting rods were provided with a reduced section near each end in order to minimize any rotating moment resulting from the relative vertical movement of the specimen and the frame. These reduced sections also minimized any restraint to rotation of the panel point at impending failure of the specimen. The specimen was centered in the testing machine and placed under a load of 5000 pounds before the supporting rods were adjusted. After the Huggenberger tensometers had been attached to the specimen, the nuts on the supporting rods were tightened in such a manner that the specimen was not stressed by being forced out of its own plane. It was found that the tensometers gave a very sensitive indication of the forcing of the specimen. The spacing of the bars, and thus the length of the individual panels, was 12 inches.

Specimen G. The set-up and the method of adjustment for specimen G were the same as used for specimen F except that this specimen was continuous over five panels.

Specimen H. Specimen H was the same as specimen C and was tested in a screw-power machine, the hardened steel platens giving a condition considered equivalent to flat ends. There being no device to correct for nonparallelism of the heads, the platens and the specimens were tried in a number of relative positions to find the position that gave the most nearly uniform distribution of load.

Strains parallel to the stiffeners were measured at a number of stations on each specimen by means of Huggenberger tensometers using a 1-inch gage length. The tensometers were mounted in pairs: one on the sheet side of the specimen and one directly opposite on the stiffener. In general, the stress was investigated at a larger number of stations than the number of tensometers available; the specimen was therefore reloaded a number of times in the range of elastic stresses, the tensometers being shifted to new stations between loadings. The load was applied in increments so that the load-stress curves could be drawn.

In the tests of specimens F and G, deflections of the outside stiffeners were measured relative to the steel I-beams of the supporting frame. Stations were located at the supporting bars and at the center of the panels.

RESULTS AND DISCUSSION

The strains measured in these tests were interpreted into stresses by simply multiplying by 10,300,000 pounds per square inch, the generally accepted value of the modulus of elasticity of the aluminum alloys. In view of the large amount of such data obtained in these tests, only a few load-stress relations are presented herein. Figures 6 and 7 show the load-stress relations for specimen A-10. The locations of the gage lines are indicated on the figures. Stresses are shown for both the sheet side and the stiffener side of the specimen. The amount of bending in the specimen is indicated by the lack of agreement between the O and the X data points (stress in the sheet and stress in the stiffener, respectively); the variation in the stress across the section is indicated by the spread between the data points and the solid lines representing the average stress, total load divided by the cross-sectional area, P/A.

The variation of stress shown in figure 7 is greater than for the other specimens except those of types E and H, which will be discussed later. The specimens of the B type, centered under load, gave the most nearly uniform distribution of stress.

The load-stress relations shown in figures 8 and 9 were obtained with specimen E-16, which had ends prepared by sawing. As would be expected from the out-of-flatness and the nonparallelism of the ends, the stress distribution between the sheet and the stiffeners is far from uniform; the stress distribution across the sheet, however, is fairly uniform. It happens that in these specimens the sheet is stressed more highly than the average and the tops of the stiffener sections are stressed less highly than the average. The indication is that, at first, the specimen was loaded only on the sheet. Under increasing loads, the specimen deflected until the ends were in uniform contact with the bearing plates in the neighborhood of 15,000 to 20,000 pounds.

The load-stress relations obtained with specimen H-16 show that the stress distribution was far from uniform but not as bad as that shown in figures 8 and 9 for specimen E-16. The distribution of stress across the specimen from one edge of the sheet to the other was, however, not so good. In this case, the stiffeners, in general, were loaded more heavily than the sheet.

The specimens with 10-gage sheet suddenly failed when the sheet buckled between the rivets, the buckle extending the full width of the sheet. In some cases the wave pattern in the sheet was not apparent before the collapse of the specimen, whereas in other cases the formation of the wave was apparent at a load a few thousand pounds less than the ultimate load. The flanges of the stiffeners were badly distorted adjacent to the buckle in the sheet and a few rivets failed in combined shear and tension.

The failures of the specimens with 16-gage sheet were preceded by the formation and the growth of a wave pattern over the entire sheet, even in the case of the continuous specimens. The pattern was first discernible at average stresses in the sheet between 31,000 and 36,500 pounds per square inch.

Table III gives the ultimate loads and the relative strengths with the values for specimen A taken as a basis of comparison in both thicknesses of sheet.

The difference in the ultimate loads of specimens A-10 and B-10 is only 2.5 percent and is probably brought about by the more uniform stress distribution resulting from centering under load. The ultimate strengths of specimens A-16 and B-16, however, indicate no benefit from the greater care of centering under load.

The ultimate load of specimen C-10 is only a little greater than that supported by the specimens tested with round ends. Since the effective slenderness ratios of the specimens are so small, 10 for flat ends and 21 for round ends, and since the failures occurred by buckling at stresses so near the yield strength of the material, this small difference is not surprising. It is shown in reference 1 that, when the column strengths are near the yield strength, the effect of the end conditions is slight for effective slenderness ratios up to about 20. For more sturdy specimens in which failures do not occur by local buckling, the effect of the end conditions is quite apparent.

The ultimate load of specimen C-16 is about 12 percent greater than those supported by the specimens tested with round ends. This difference is considerably greater than that for the specimens with 10-gage sheet. The greater difference may be explained as follows: The failures of the specimens tested with round ends followed closely after the formation of the buckles in the sheet. In the case of the specimens with 16-gage sheet the buckles formed at stresses much lower, relative to the yield strength of the material, than in the case of specimens with 10-gage sheet. Since the effective centroid of the section shifted as the buckling of the sheet developed and since the line of action of the load was fixed by the knife-edge bearings, there was an effective eccentricity that increased as the test progressed, tending to bring on early failure. Now, in the case of the specimen tested with flat ends, although the sheet buckled at about the same stress as in the test with round ends, the line of action of the load shifted with the changing effective centroid because the heads were fixed against tipping; consequently, there was no effective eccentricity and less tendency for early failure. From this discussion and these data, one should expect the difference in the results of tests with flat ends and with round ends to increase as the thickness of the sheet decreases.

In the comparison of the results of the 12- and 24-inch specimens (C and D), it is seen that the corresponding values agree within about 3 percent. As pointed out, the difference in lengths should have a relatively small effect on the ultimate loads supported because the stresses are so near the compressive yield strengths and the failures occurred by local buckling.

The comparison of the ultimate strengths of specimens C and E shows that the specimens with sawed ends are weaker by about 5 to 7 percent than those with carefully prepared ends. This difference might have been in the opposite direction had the sawed ends been such as to produce the high stresses in the stiffeners that are relatively stronger than the sheet.

The ultimate load of continuous specimen F-10 is the greatest for the specimens with 10-gage sheet and that of F-16 is practically equal to the greatest for the specimens with 16-gage sheet. The ultimate loads agree better with the results of the tests with flat ends than they do with the results of tests with round ends. As was pointed out in connection with specimens of types A, B, and C, these stiffened flat sheet specimens did not fail by column action but by local buckling of the sheet. Since the type F specimens were so uniformly loaded and free from deflection as a unit, the line of action of the load could shift with the center of resistance of the specimens, giving the same condition as in the specimens with flat ends.

The ultimate loads of the type G specimens, continuous over five panels, are within 4 percent of those supported by the type F specimens with three continuous panels.

The measured deflections of the continuous specimens indicated some movement of the specimen relative to the supporting frame. Rather than deflecting into a curve with points of contraflexure at the points of support, the specimens deflected into curves with two points of contraflexure in each panel. In other words, the centers of all panels deflected in the same direction, rather than adjacent panels going in opposite directions, as would undoubtedly be the case if the slenderness ratio of the segments were great enough for column action to be present.

The ultimate strength of specimen H-16, which was tested between nonparallel bearing plates in a screw-power machine, is about 2 percent less than that supported by specimen C-16, which was tested with carefully alined bearing plates in a hydraulic-power machine, and is about 5 percent greater than that supported by specimen E-16, which had sawed ends.

The ultimate loads and the average stresses at failure for specimens of types C, D, F, and G are within 2 percent of the average of the four individual values. This agreement would indicate that, for specimens designed to fail at stresses near the yield strength of the material, the length of the specimen is of insignificant importance provided the effective slenderness ratio does not exceed about 20. It is also indicated that specimens continuous over several short panels support ultimate loads nearly equal to those supported by simple specimens with flat ends.

CONCLUSIONS

The following conclusions were drawn from the data and the discussion presented in this report and apply to stiffened sheet panels which have effective slenderness ratios less than about 20 and are designed to fail at average stresses (P/A) close to the yield strength of the material:

1. In the restricted range of slenderness ratios under consideration, the length of the specimen has an insignificant effect on the ultimate compressive load supported by the specimen.

2. The condition of the ends, whether round or flat, has only a small effect on the strength of the specimen if the buckling strengths of the sheet and stiffeners are nearly

equal. In the case of specimens where either the sheet or the stiffener is relatively stronger than the other, the use of flat ends will result in a higher test load than will the use of round ends.

3. For the type of specimens under consideration, the added refinement of centering under load in tests using knife-edge bearings does not appear to be justified by the difference in the ultimate loads of specimens centered by this procedure and specimens centered by direct measurement to the centroid.

4. The ultimate loads supported by the continuous specimens are close to those supported by simple specimens tested with flat ends. Continuous specimens with hinged supports at the panel points offer a means of obtaining a high ultimate load without introducing a degree of end restraint at the panel points greater than that present in the prototype. In this respect, the continuous-panel test is superior to the ordinary flat-end test because, in flat-end tests, one cannot be sure that the degree of end restraint does not exceed that encountered in the prototype.

5. The precision with which the ends of the specimen are finished flat and parallel as well as the care exercised in the alinement of the specimen in the testing machine have no consistent effect on the ultimate loads supported by the specimens, but they are reflected in a more nearly uniform distribution of the stresses measured in the elastic range.

6. Whether short specimens are tested in a hydraulic-power testing machine or in a screw-power machine seems to make no difference in the ultimate loads. In either case the stress distribution should be made as nearly uniform as possible by the use of well-prepared specimens and parallel platens.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., April 18, 1941.

REFERENCE

1. Templin, R. L., Sturm, R. G., Hartmann, E. C., and Holt, M.: Column Strength of Various Aluminum Alloys. Tech. Paper No. 1, Aluminum Res. Lab., Aluminum Co. of Am., 1938.

TABLE I

DESCRIPTION OF SPECIMENS AND RESULTS OF TESTS

Specimen	Ends flat and parallel within (in.)	Cross-sectional area, A (sq in.)	Ultimate load, P (lb)	Average stress, P/A (lb/sq in.)	End condition in test	Wave pattern noticeable at load (lb)	Remarks
A-10	0.0010	2.298	97,500	42,430	Round	97,500	Centered by measurement to centroid.
B-10	.0010	2.298	[a]100,000	43,520	Round	99,000	Centered by strain measurements.
C-10	.0010	2.295	103,000	44,880	Flat	100,000	
D-10	.0015	2.291	102,400	44,700	Flat	------------	
E-10	.0390	2.295	97,750	42,590	Flat	------------	Sawed ends.
F-10	.0015	2.295	105,500	45,970	Continuous	------------	Continuous over three panels.
G-10	.0020	2.300	101,500	44,130	Continuous	99,000	Continuous over five panels.
A-16	.0015	1.765	68,600	38,870	Round	55,000	Centered by measurement to centroid.
B-16	.0015	1.765	68,000	38,530	Round	60,000	Centered by strain measurements.
C-16	.0010	1.765	75,500	43,340	Flat	63,000	
D-16	.0010	1.769	74,300	42,000	Flat	62,000	
E-16	.0395	1.765	71,500	40,510	Flat	45,000	Sawed ends.
F-16	.0010	1 768	76,400	43,210	Continuous	60,000	Continuous over three panels.
G-16	.0020	1.772	[b]75,000	42,330	Continuous	65,000	Continuous over five panels.
H-16	.0015	1.769	75,000	42,400	Flat	68,000	Tested in screw-power machine.

[a] Held temporarily.

[b] Held momentarily.

TABLE II

SUMMARY OF MECHANICAL PROPERTIES OF MATERIALS

Form	Nominal thickness (in.)	Tensile strength (lb/sq in.)	Tensile yield strength, Offset = 0.2% (lb/sq in.)	Elongation in 2 in. (percent)	Compressive yield strength, Offset = 0.2% (lb/sq in.)
10-gage sheet	0.102	69,200	54,300	20.0	43,100
16-gage sheet	.081	72,250	54,700	18.3	45,000
Stiffener	.078	70,810	52,900	15.9	46,400

TABLE III

RESULTS OF TESTS ON STIFFENED FLAT SHEET SPECIMENS

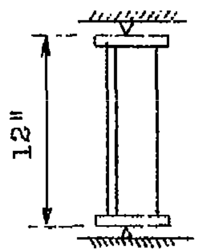
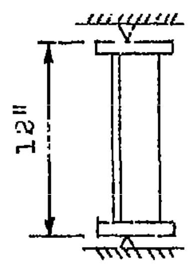
Specimen and method of testing			10-gage sheet		16-gage sheet	
			Ultimate load (lb)	Relative strength	Ultimate load (lb)	Relative strength
A		Tested with round ends (knife edges) centered by measurement in hydraulic-type machine with heads equipped with leveling rings. Accurately machined ends.	97,500	1.00	68,600	1.00
B		Tested with round ends (knife edges) centered under load in hydraulic-type machine with heads equipped with leveling rings. Accurately machined ends.	100,000	1.03	68,000	0.99

TABLE III (Continued)

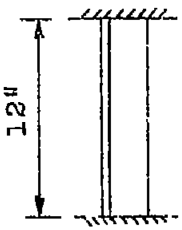
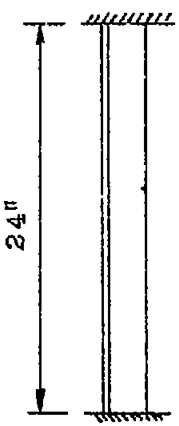
Specimen and method of testing			10-gage sheet		16-gage sheet	
			Ultimate load (lb)	Relative strength	Ultimate load (lb)	Relative strength
C	 12"	Tested with flat ends in hydraulic-type machine with heads equipped with leveling rings. Accurately machined ends.	103,000	1.06	76,500	1.12
D	 24"	Tested with flat ends in hydraulic-type machine with heads equipped with leveling rings. Accurately machined ends.	103,400	1.05	74,300	1.08

TABLE III (Continued)

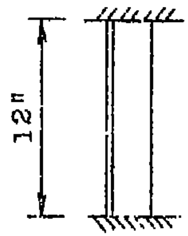
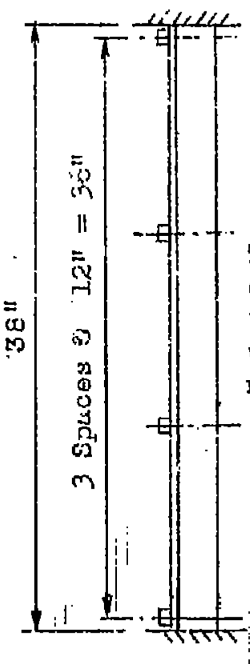
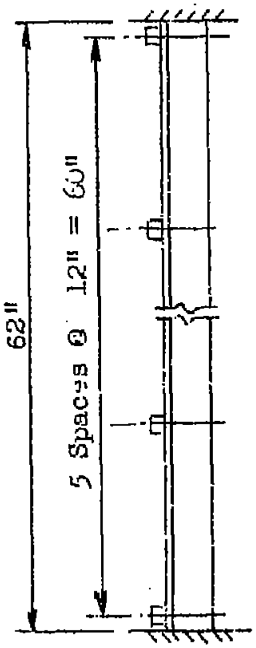
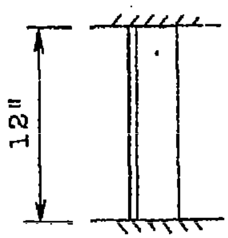
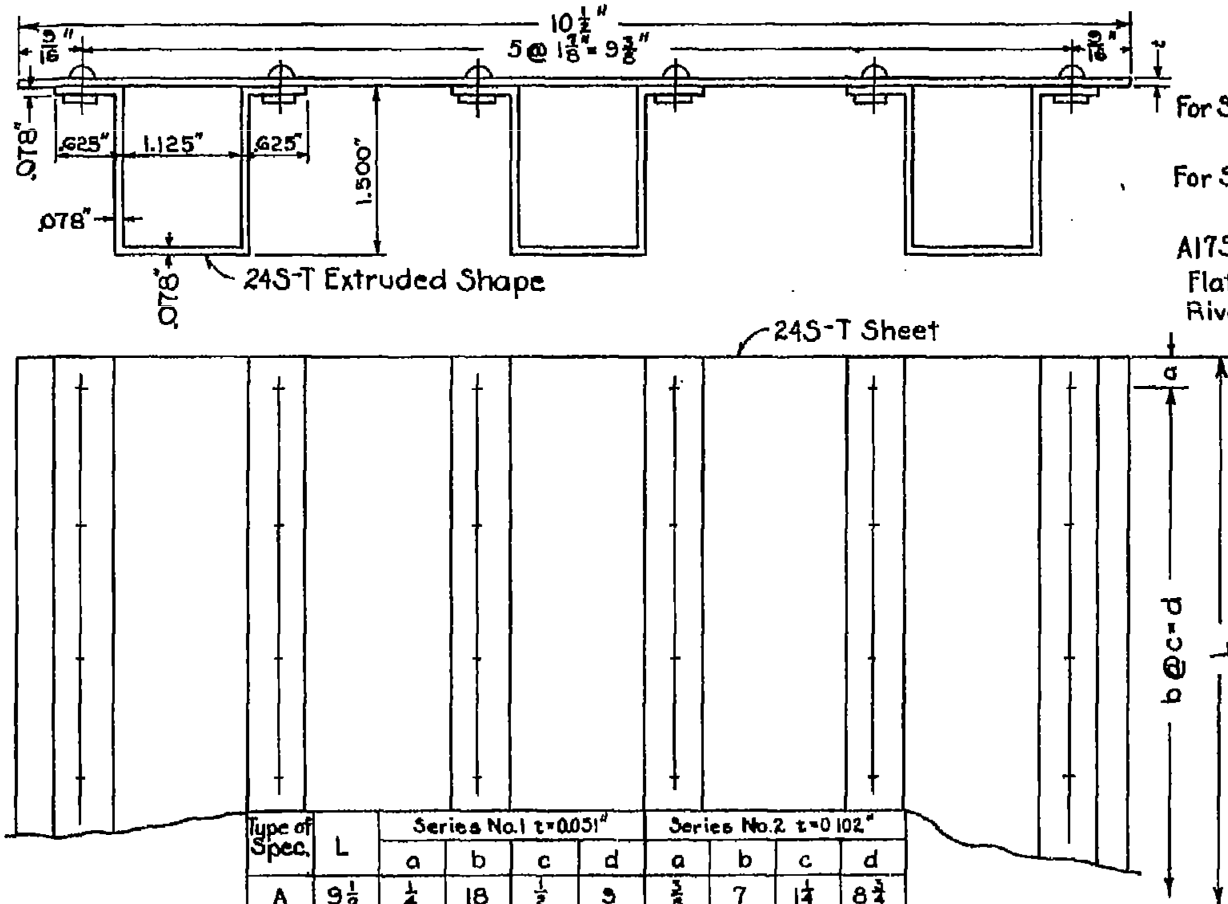
Specimen and method of testing			10-gage sheet		16-gage sheet	
			Ultimate load (lb)	Relative strength	Ultimate load (lb)	Relative strength
E		Tested with flat ends in hydraulic-type machine with heads equipped with leveling rings. Rough sawed ends.	97,750	1.00	71,500	1.04
F		Tested as a column continuous over three panels in hydraulic-type machine with heads equipped with leveling rings. Accurately machined ends.	105,500	1.08	76,400	1.11

TABLE III (Concluded)

Specimen and method of testing			10-gage sheet		16-gage sheet	
			Ultimate load (lb)	Relative strength	Ultimate load (lb)	Relative strength
G		Tested as a column continuous over five panels in hydraulic-type machine with heads equipped with leveling rings. Accurately machined ends.	101,500	1.04	75,000	1.09
H		Tested with flat ends in screw-power machine with heads not equipped with leveling rings. Accurately machined ends.	--------	--------	75,000	1.09



For Series No.1: t = 0.051", B&S Gage 16
rivet diameter = 1/8"
For Series No.2: t = 0.102", B&S Gage 10
rivet diameter = 3/16"
A17S-T Button Head Rivets;
Flat driven head on stiffener side;
Rivets driven cold.

Type of Spec.	L	Series No.1 t = 0.051"				Series No.2 t = 0.102"			
		a	b	c	d	a	b	c	d
A	$9\frac{1}{2}$	$\frac{1}{4}$	18	$\frac{1}{2}$	9	$\frac{3}{8}$	7	$1\frac{1}{4}$	$8\frac{3}{4}$
B	$9\frac{1}{2}$	$\frac{1}{4}$	18	$\frac{1}{2}$	9	$\frac{3}{8}$	7	$1\frac{1}{4}$	$8\frac{3}{4}$
C	12	$\frac{1}{4}$	23	$\frac{1}{2}$	$11\frac{1}{2}$	$\frac{3}{8}$	9	$1\frac{1}{4}$	$11\frac{1}{4}$
D	24	$\frac{1}{4}$	47	$\frac{1}{2}$	$23\frac{1}{2}$	$\frac{23}{64}$	21	$1\frac{7}{64}$	$23\frac{19}{64}$
E	12	$\frac{1}{4}$	23	$\frac{1}{2}$	$11\frac{1}{2}$	$\frac{3}{8}$	9	$1\frac{1}{4}$	$11\frac{1}{4}$
F	38	$\frac{1}{4}$	75	$\frac{1}{2}$	$37\frac{1}{2}$	$\frac{11}{32}$	31	$1\frac{13}{64}$	$37\frac{19}{64}$
G	62	$\frac{1}{4}$	123	$\frac{1}{2}$	$61\frac{1}{2}$	$\frac{5}{16}$	51	$1\frac{13}{64}$	$61\frac{23}{64}$

STIFFENED FLAT SHEET PANELS
FOR EDGE COMPRESSION TESTS.

FIGURE 1

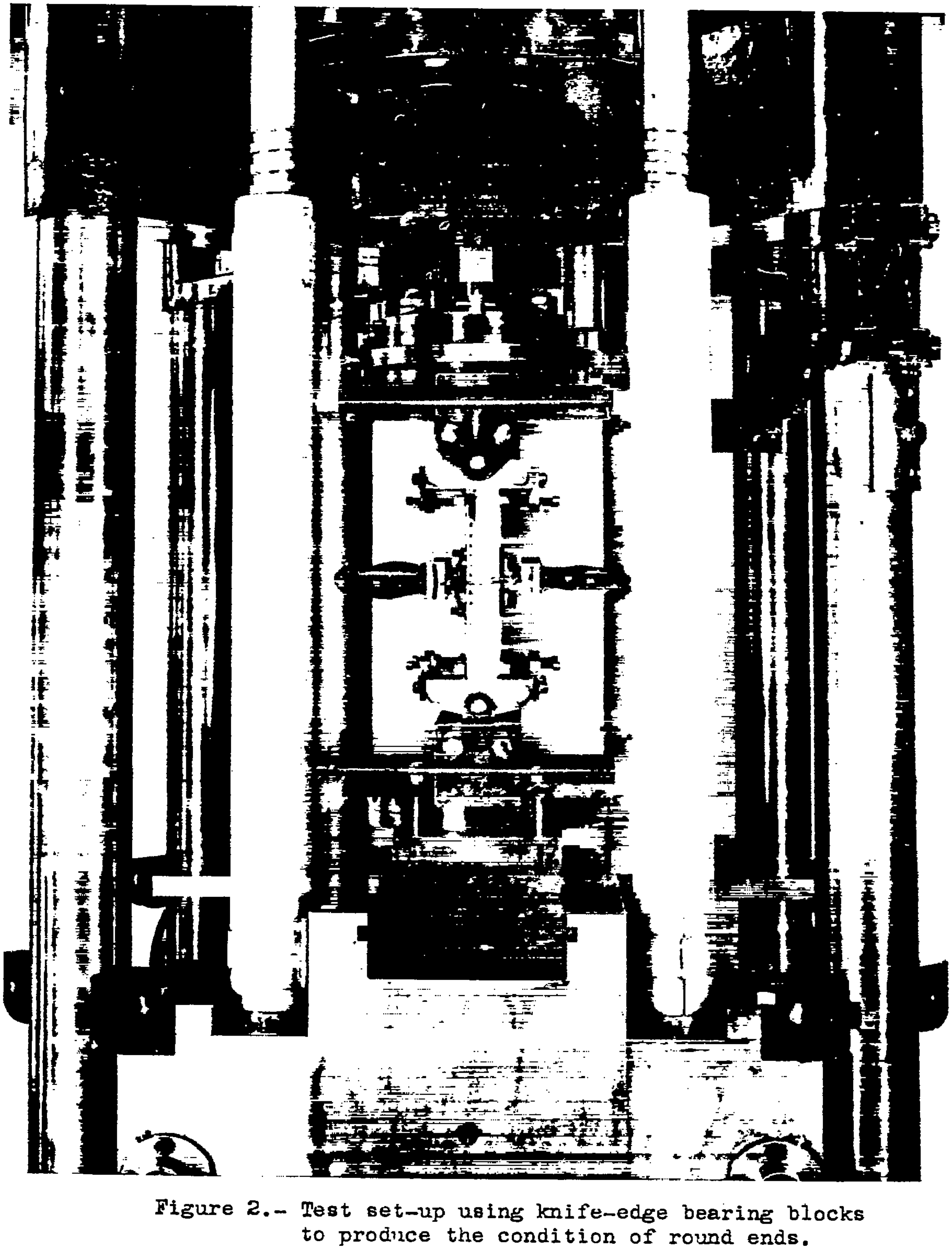


Figure 2.- Test set-up using knife-edge bearing blocks to produce the condition of round ends.

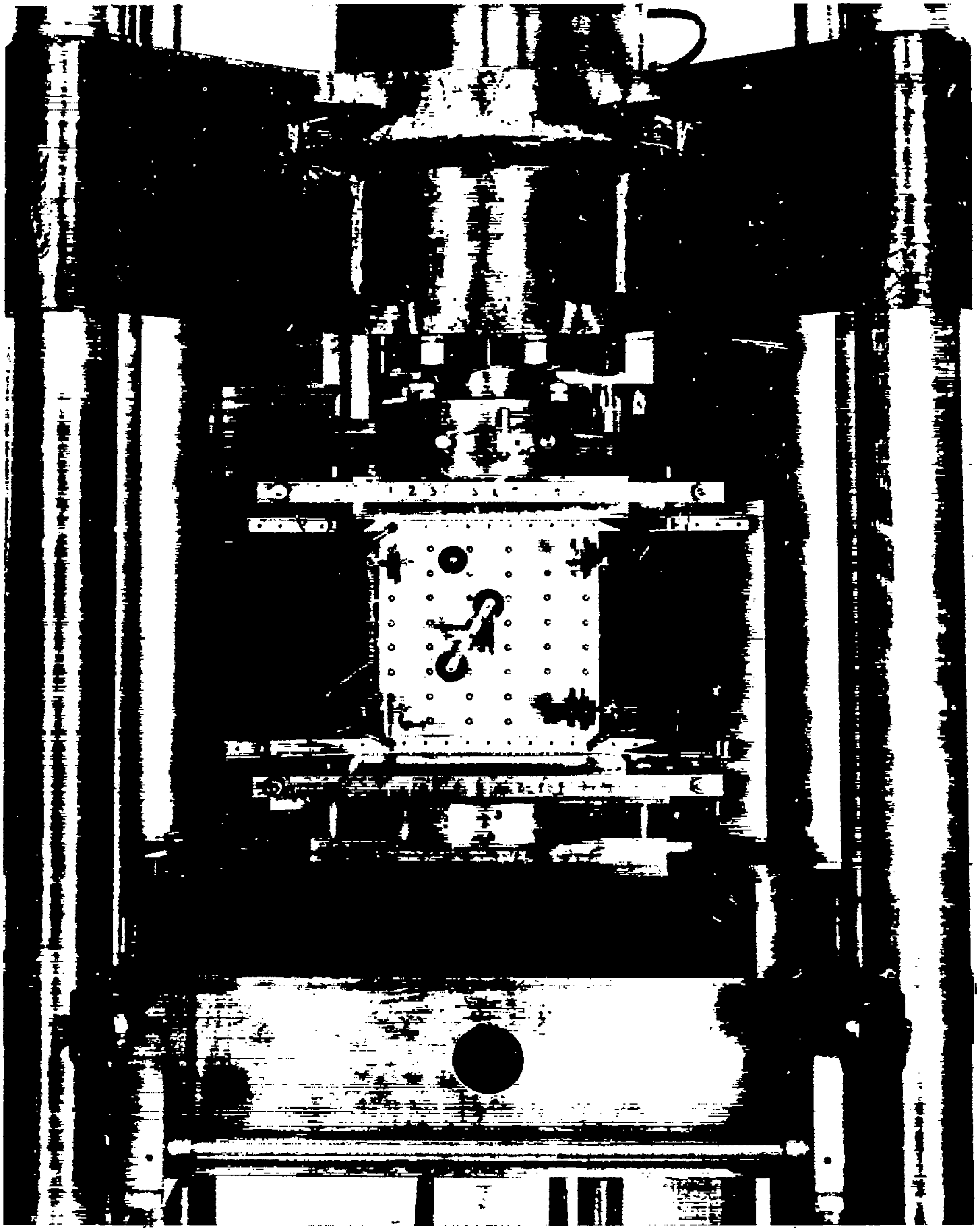


Figure 3.- Test set-up using fixed heads of testing machine to produce the condition of flat ends.

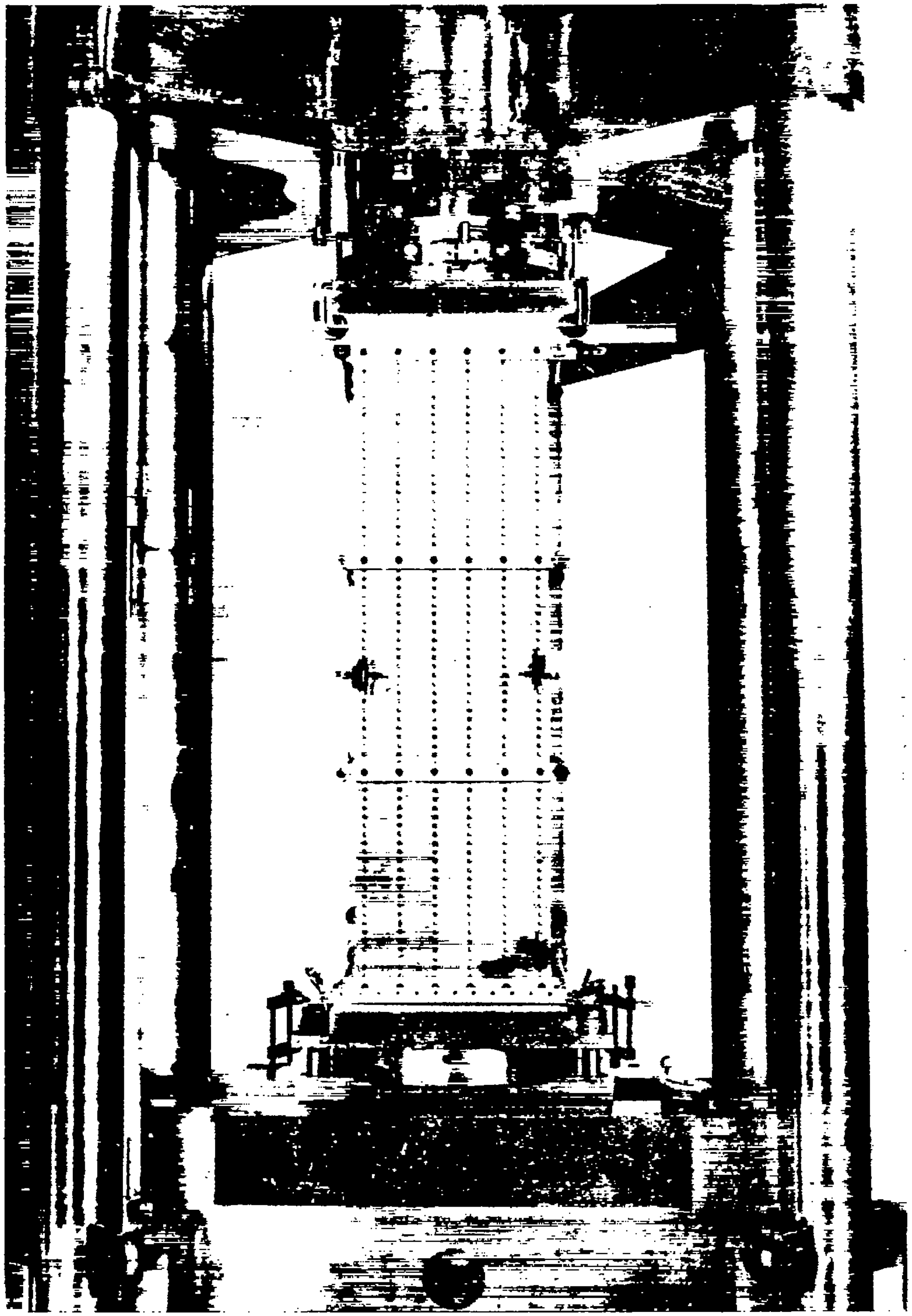


Figure 4.- Specimen with intermediate supports giving three continuous panels.

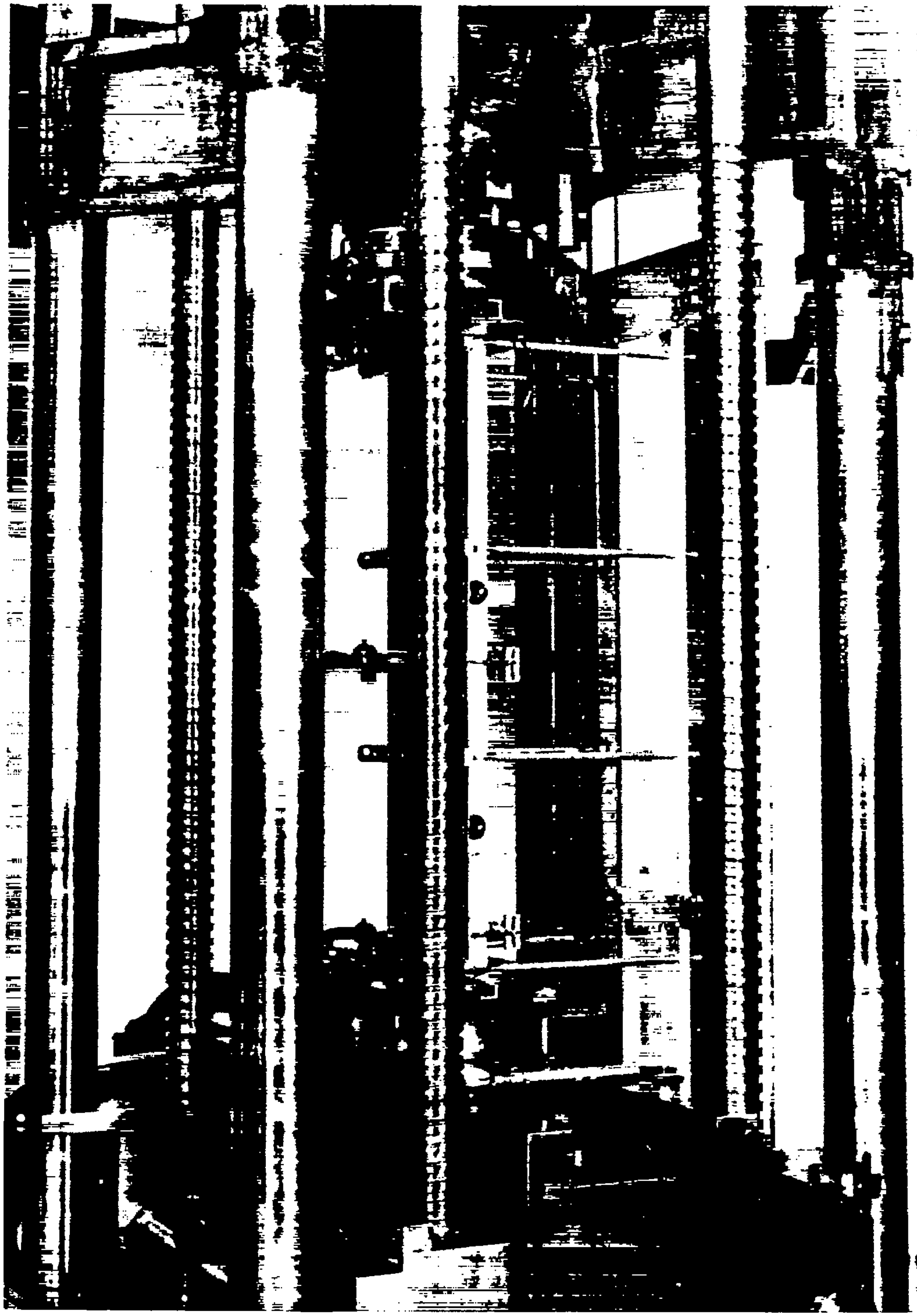


Figure 5.- Specimen with intermediate supports giving three continuous panels.

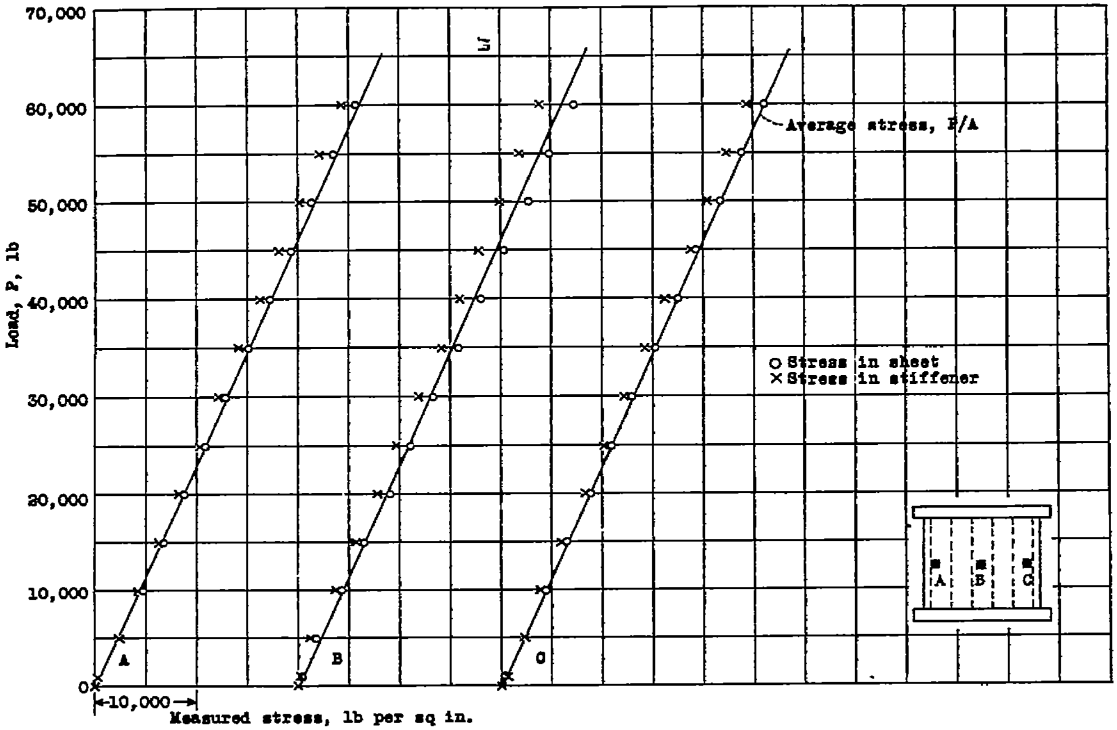


Figure 6.- Load-stress curves for stiffened flat sheet under compressive load. 24S-T aluminum; specimen A-10; 10-gage sheet; thickness, 0.1008 inch; measured stress = measured strain × 10,300,000 lb per sq in.

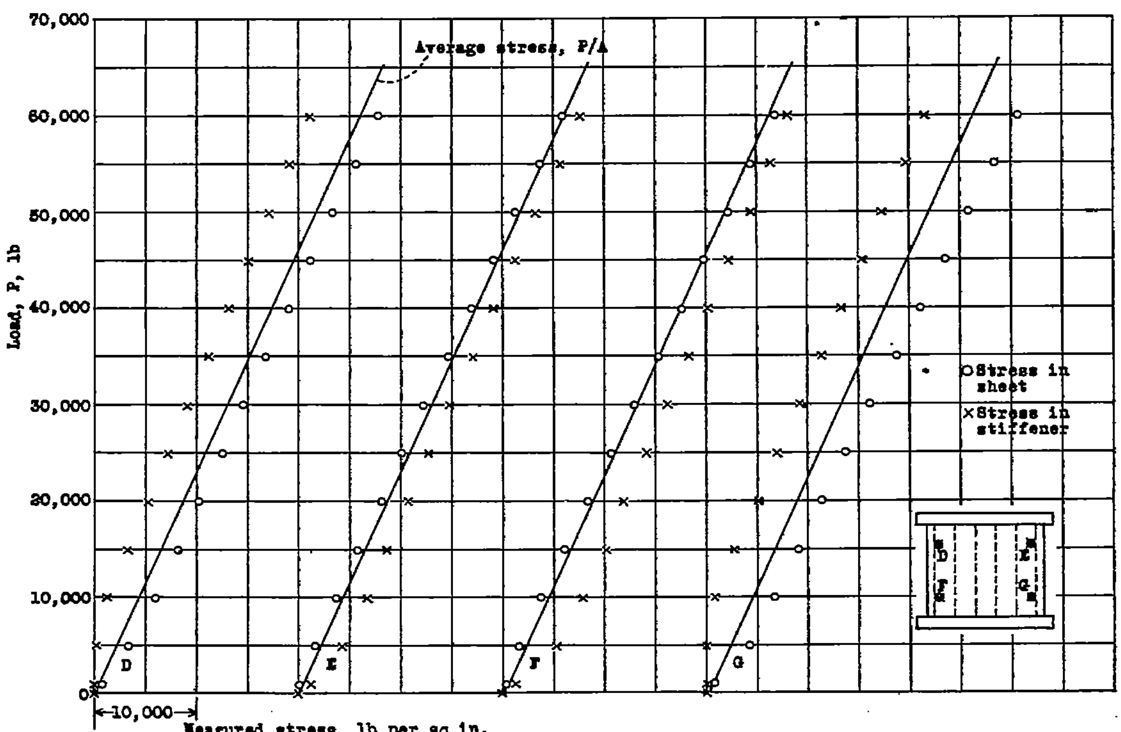


Figure 7.- Load-stress curves for stiffened flat sheet under compressive load. 24S-T aluminum alloy; specimen A-10; 10-gage sheet; thickness, 0.1008 inch; measured stress = measured strain × 10,300,000 lb per sq in.

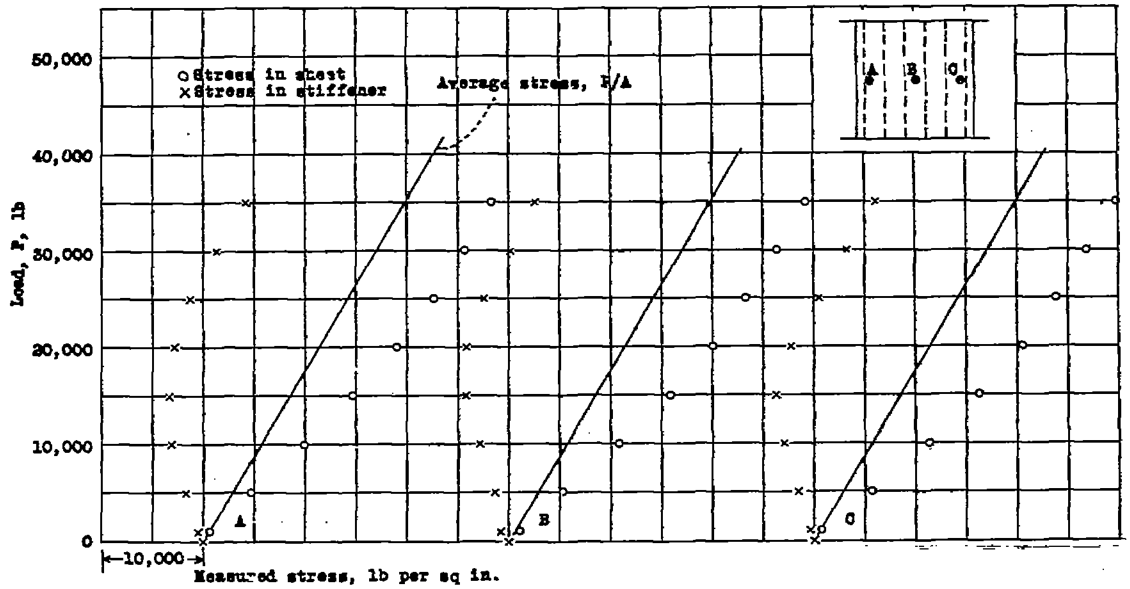


Figure 8.- Load-stress curves for stiffened flat sheet under compressive load. 24S-T; specimen E-16; 16-gage sheet; thickness, 0.0500 inch; measured stress = measured strain × 10,300,000 lb per sq in.

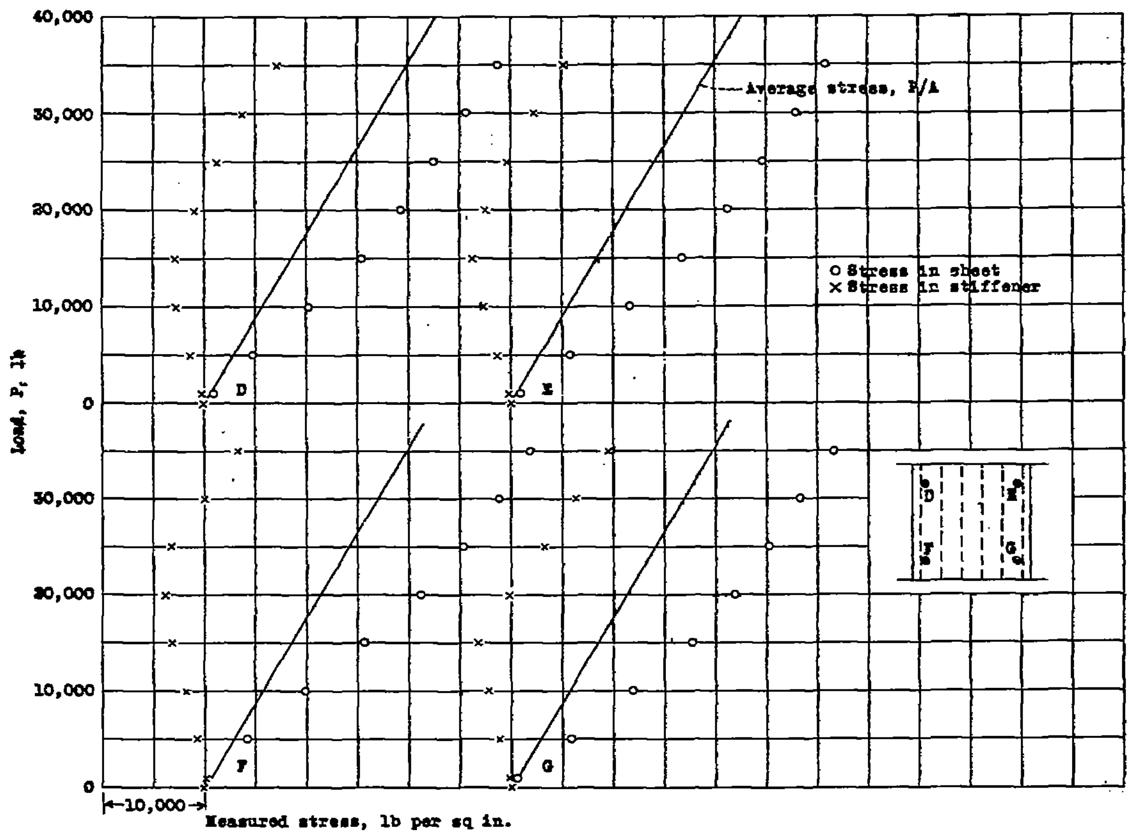


Figure 9.- Load-stress curves for stiffened flat sheet under compressive load. 24S-T aluminum alloy; specimen E-16; 16-gage sheet; thickness, 0.0500 inch; measured stress = measured strain × 10,300,000 lb per sq in.